Risk Management Guidelines for Petroleum Storage Tank Sites

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PREFACE

The *Risk Management Guidelines for Petroleum Storage Tank Sites – 2001* provides a site management process specifically for soil and groundwater contamination originating from existing or former petroleum storage facilities. The numerical criteria, risk management objectives and technical information presented in this document are a compilation of information from the following documents:

- Alberta Environment, 1994. *Remediation Guidelines for Petroleum Storage Tank Sites – 1994*
- Canadian Council of Ministers of the Environment, 2000. *Canada-Wide Standards for Petroleum Hydrocarbons (PHC) in Soil*
- Alberta Environment, 2001. *Alberta Soil and Water Quality Guidelines for Hydrocarbons at Upstream Oil and Gas Facilities*
- Alberta Environment, 2000. *Guidelines for Managing Risks at Contaminated Sites in Alberta (Draft)*

The changes incorporated into these Guidelines are intended to update remediation criteria and provide a process for determining alternate site-specific management objectives for a wider range of receptors than was encompassed in the 1994 Guidelines.

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1.0 INTRODUCTION

The "Risk Management Guidelines for Petroleum Storage Tank Sites - 2001" (hereafter referred to as the Guidelines) have been developed to assist both the owners and operators of petroleum storage tank (PST) systems and the regulatory authority in the remediation or management of sites contaminated by leakage or spillage of petroleum products. These Guidelines have been developed through use of a risk-based approach which is designed to ensure the protection of human health, safety and the environment. The Guidelines will provide uniform standards for the remediation and management of contaminated PST sites in Alberta.

The intent of the Guidelines is to manage contamination related to hydrocarbon fuels at retail and some bulk distribution outlets. Since most of these facilities are within urban centres, the risk management approach is developed principally for these situations. The Guidelines apply to both underground and aboveground storage tank facilities which contain or have contained the following substances:

- gasoline
- diesel
- heating oil
- aviation fuel

The Guidelines are not to be applied in the following circumstances:

- the contaminant is used oil
- the PST site is a component of a facility where there are other contaminant sources (e.g., industrial plant, upstream oil and gas lease, etc.)
- the contaminant is a solvent or a related hydrocarbon

If the contaminant is not a hydrocarbon fuel, the Proponent should contact the appropriate Alberta Environment regional office for directions on the applicable remediation criteria.

PST sites that have completed remediation based on the 1991 and 1994 Alberta PST Guidelines do not need to be remediated to the 2001 Guideline criteria. In situations where PST sites are in the process of remediation when these Guidelines are released, the proponent may opt to use either the 1994 or 2001 Guidelines.

1.1 Objectives

The principle objective of the Guidelines is to establish minimum requirements for assessment and management of risks associated with petroleum contaminated soil and groundwater. The Guidelines also establish a process whereby the owner or operator of a PST facility works with the regulatory authority to ensure the protection of human health, safety and the environment.

1.2 Background

The Alberta approach is based on the principles of risk assessment and risk management for contaminated sites. The Guidelines present numerical criteria above which either remediation or a risk assessment must be undertaken in order to address the potential risks to human health and safety, and to the environment. The Guidelines are the result of experience gained in Alberta developing and using previous PST guidelines (i.e., 1991 and 1994 versions) and a detailed review of recent publications from Alberta Environment and the Canadian Council of Ministers of the Environment.

1.3 Format of Guidelines

The Guidelines describe the process to be followed by a PST owner or operator in remediating or managing contaminated PST sites. The process is outlined initially in flow chart form, and the responsibilities of the owner or operator are identified at each stage of the process. Numerical risk management criteria are presented for soil and groundwater, together with the recommended approach for determination of the applicable remediation levels. The numerical criteria can be utilized directly in remediation and risk management decisions, or the tank owner may undertake a detailed risk assessment to define alternate site-specific management objectives. Requirements for both the site investigation and verification of soil and groundwater remediation are also defined.

1.4 Definitions

"Adverse effect" means impairment of or damage to the environment, human health or safety or property.

"Aquifer" means an underground water-bearing formation that is capable of yielding water.

"Coarse-grained soil" means a soil having median grain size (D_{50}) greater than 75 microns.

"Criteria" means generic numerical values of hydrocarbon concentrations in soil or groundwater designed to be protective of human health and the environment.

"Delineate", for the purpose of the Guidelines, means identification of the lateral and vertical extent of contamination exceeding the appropriate generic remediation criteria for the site.

"Department" means the Alberta Department of Environment.

"Fine-grained soil" means a soil having median grain size (D_{50}) less than 75 microns.

"Groundwater" means all water under the surface of the ground whether in liquid or solid state.

"Petroleum hydrocarbon" means the mixture of compounds found in or derived from organic geological substances such as oil. For the purposes of these Guidelines petroleum hydrocarbons are considered to be comprised of four fractions defined as follows:

- F1 ($C_6 - C_{10}$)
- F2 ($>C_{10} - C_{16}$)
- F3 ($>C_{16} - C_{34}$)
- F4 ($>C_{34}$)

"Proponent" means the owner, operator or other responsible party proposing or undertaking remediation of a PST site.

"Remediation" means the removal or reduction of contaminant concentrations to an acceptable land use endpoint based on risk-based generic numerical objectives.

"Risk assessment" means characterization of the nature, magnitude and likelihood of adverse effects on human health or ecosystems from exposure to one or more contaminating substances through various routes of exposure (i.e., pathways).

"Risk management" means eliminating or controlling one or more risk assessment components (contaminants, receptors and/or pathways) with the goal of achieving risk reduction on a contaminated property. Remediation is one possible risk management option.

"Stakeholder" when used with risk assessment means the property owner, adjacent property owners/residents, local health officials and municipal authorities, Alberta Environment, and any others who may be directly affected by the contamination and risk management plan.

2.0 NOTIFICATION

2.1 Alberta Environment Requirements

The Environmental Protection and Enhancement Act and the Release Reporting Regulation deal with the release of substances into the environment and set out requirements for the reporting of such releases to Alberta Environment. The requirement to report applies to releases of all substances that may cause an adverse effect. The Release Reporting Guideline (June 2001) is designed to clarify how the Department will interpret the regulation.

The person who causes or permits the release or the person having control of the released substance is responsible for reporting the release and for determining whether there was an adverse effect.

In the case of most petroleum storage tank sites, the release has occurred over a period of time. The Release Reporting Guideline clarifies the reporting requirements where there is a cumulative effect of numerous small releases that could result in a potential adverse effect. If small releases continue at the same location over a prolonged period of time, there is a potential for an adverse effect. The person who causes or caused the release or has control of the released substance shall report the release and the potential adverse effect immediately upon discovery of the release.

The release must be reported as soon as a person knows or ought to have known of the release. This means that the release must be reported at the first available opportunity and not when it is convenient. Reports should be made to the Environmental Assurance Service Response Centre by phoning the 24-hour toll free response number at 1-800-222-6514.

Copies of the Release Reporting Guideline may be obtained by contacting:

REGULATORY APPROVALS CENTRE
Alberta Environment
Main Floor, Oxbridge Place
9820 – 106 Street
Edmonton, Alberta T5K 2J6

Phone:780/427-6311

or

INFORMATION CENTRE
Alberta Environment
Main Floor, Great West Life Building
9920 – 108 Street
Edmonton, Alberta T5K 2M4

Phone: 780/944-0313
Fax: 780/427-4407
env.infocent@gov.ab.ca

The Release Reporting Guideline can also be viewed by accessing the Alberta Environment website http://www.gov.ab.ca/env/protenf/publications/RelRepGuideline.pdf. The PDF format requires the Adobe Acrobat Reader in order to view. This website has a free download.

2.2 Alberta Fire Code Requirements

The 1997 Alberta Fire Code identifies notification procedures for both a product loss and the removal of underground storage tanks. Reference to the *authority having jurisdiction* refers to a safety codes officer in the fire discipline exercising authority in accordance with the Safety Codes Act. In most cases, notification under the Fire Code is made to the municipality's fire department. Where the municipality is non-accredited under the fire discipline, notification for non-emergency provisions of the Fire Code should be made to the Petroleum Tank Management Association of Alberta. Notification for releases of flammable or combustible liquid, which necessitates immediate attention to mitigate risk of fire or explosion, is to be made to the municipal fire department.

4.1.6.3. (5) When a loss of flammable liquid or combustible liquid occurs from a spill or leak, the owner shall ensure that:

- b) the fire department and the authority having jurisdiction are notified forthwith if the quantity of liquid spilled or leaked
  - i) exceeds 50 L in aggregate, or
  - ii) is sufficient to cause a sheen on nearby surface water.

4.3.16.3. (1) The owner of a storage tank shall immediately notify the authority having jurisdiction in the event of a spill of more than 50 litres in accordance with Sentence 4.1.6.3.(5) or within 24 hours after a leak or discharge is suspected, as indicated by any one of the following:

- a) any unexplained loss or gain of 0.5 per cent or more of the throughput from an underground storage tank or a loss of 2.0 per cent or more of the throughput from an aboveground storage tank, for each stored product in a calendar month, as indicated by the recording and reconciliation of inventory records, done in conformance with Sentence 4.3.16.1.(3),
- b) inventory reconciliations showing five consecutive days of unexplained product losses,
- c) inventory reconciliations showing 18 days of unexplained losses in one calendar month,
- d) the level of water at the bottom of an underground storage tank exceeds 50 mm,
- e) failure of a precision leakage test which indicates a loss or gain of product,
- f) failure of a hydrostatic piping test,
- g) analysis or other evidence of product in a monitoring well or drinking water well,
- h) the presence of free or dissolved product onsite or offsite in the soil, groundwater, surface water, sewer lines, utility lines, water supply lines, basements, crawl space or on the ground surface, or
- i) the signal of any warning systems associated with monitoring devices.

(2) A person shall forthwith report to the authority having jurisdiction and the fire department if he has information about a leak of flammable liquid or combustible liquid that

a) is based on analysis or other evidence of flammable liquid or combustible liquid in a monitoring well or a water well, or
b) indicates the presence of free or dissolved flammable liquid or combustible liquid in soil, groundwater, surface water, sewer lines, utility lines, water supply lines, basements, crawl space or on the ground surface.

4.10.3.1. (1) When an underground storage tank system has no further use or has been out of service for 2 years
a) the owner shall notify the authority having jurisdiction in writing at least 30 days prior to the removal of an underground storage tank system.

(2) If the soil surrounding the storage tanks described in Sentence (1) is found to be contaminated, the owner shall
a) notify the authority having jurisdiction,
b) when requested, provide a report showing the extent of the site soil contamination, and
c) remove, treat or replace the contaminated soil in a manner acceptable to the authority having jurisdiction.

Failure to notify officials of a product release or tank removal contravenes the Safety Codes Act and Regulations and carries a fine of up to $15,000.

Additional information regarding requirements under the Alberta Fire Code may be obtained by contacting:

Petroleum Tank Management Association of Alberta
Suite 980
10303 Jasper Avenue
Edmonton, Alberta T5J 3N6

Phone: 780/425-8265
www.ptmaa.ab.ca

3.0 THE RISK MANAGEMENT PROCESS

The site assessment and risk management process is shown schematically in Drawing No. 3.1. The flow chart presents a process to be used by the Proponent for the remediation or management of a contaminated PST site, and indicates the role of the Department in working with the Proponent. The key steps are described in the following paragraphs.

3.1 Site Investigation

Once a spill or leak from a PST has been identified, the Proponent should undertake a site investigation. The site investigation methodology and level of detail may vary between sites, however the purpose is always to delineate subsurface contamination in sufficient detail to develop a risk management plan. Site specific detailed information is usually required on the site geology and hydrogeology, but data relevant to the assessment of potential human and environmental impacts could also be obtained.

Site investigation requirements are described in Appendix A.

3.1.1 Determination of Soil Type

Generic guidelines are available for two soil types, Coarse and Fine. These soil types are defined as having a median grain size (D_{50}) greater or less than 75 microns, respectively.

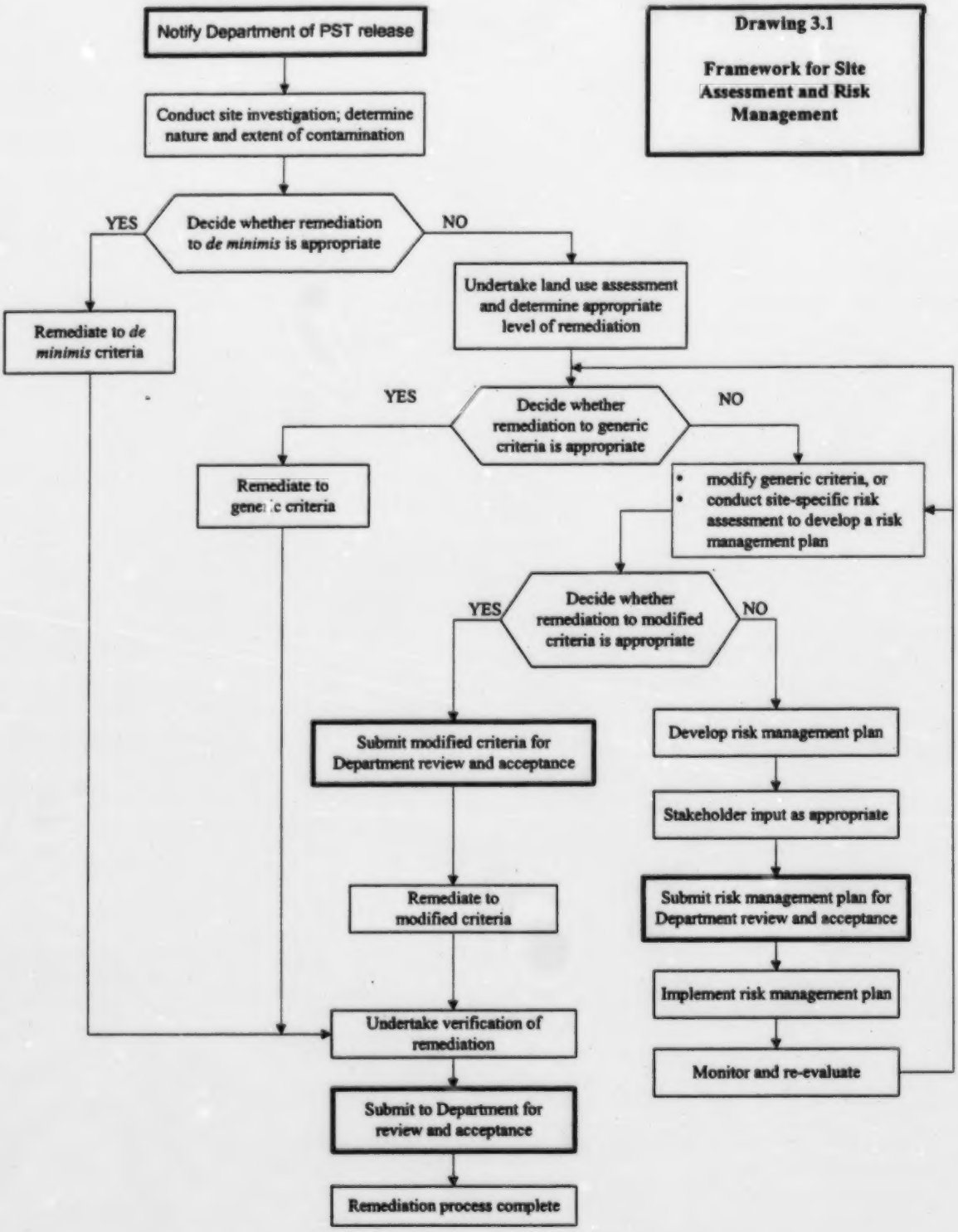
Selection of the appropriate set of guidelines is based on the soil type that controls contaminant migration at the site, based on professional judgement. For example, a continuous layer of Coarse soil beneath the water table will often govern groundwater flow in the saturated zone, even though its thickness may be small in relation to the total thickness of saturated Fine soils. In cases where it is not clear which soil type should be applied at a site, the more conservative numerical criterion will be applied to each parameter.

3.2 Contaminant Source Removal

The source(s) of contamination must be removed prior to the initiation of any risk management program. Sources may include leaking tanks, lines and any liquid petroleum hydrocarbons detected on the water table surface.

3.3 Remediation to De Minimis Criteria

Depending on the nature and extent of the contamination identified during the site investigation, the Proponent may choose to remediate the site to the most stringent criteria recognized by the Department. These *de minimis* criteria specify contaminant concentrations at or below which no adverse human or environmental effects are anticipated, and are sufficiently stringent to accommodate unrestricted future land use. The *de minimis* criteria for each chemical parameter is the lowest value among the numerical criteria listed in Tables 1, 2, 3 and 4.


Notify Department of PST release
Conduct site investigation; determine nature and extent of contamination
Decide whether remediation to *de minimis* is appropriate
YES
NO
Remediate to *de minimis* criteria
Undertake land use assessment and determine appropriate level of remediation
Decide whether remediation to generic criteria is appropriate
YES
NO
Remediate to generic criteria
modify generic criteria, or
conduct site-specific risk assessment to develop a risk management plan
Decide whether remediation to modified criteria is appropriate
YES
NO
Submit modified criteria for Department review and acceptance
Develop risk management plan
Stakeholder input as appropriate
Remediate to modified criteria
Submit risk management plan for Department review and acceptance
Implement risk management plan
Undertake verification of remediation
Monitor and re-evaluate
Submit to Department for review and acceptance
Remediation process complete

Drawing 3.1

Framework for Site Assessment and Risk Management

3.4 Remediation to Generic Criteria Based on Land Use

3.4.1 Land Use Assessment

If the Proponent chooses not to remediate to the de minimis criteria, then further work must be conducted to determine the appropriate land use based on existing zoning or development restrictions. The land use assessment includes a review of local municipal zoning restrictions to assess the full range of allowable uses for the PST site and adjacent properties. Remediation criteria are based on the most sensitive allowable land use.

The remediation criteria in Tables 1, 2 and 3 are derived from three generic land uses based on normal activities on the land.

Residential Land Use is where the primary activity is residential or recreational activity. This land use includes campground areas and urban parks, but not wildlands in national or provincial parks.

Commercial Land Use is where the full range of allowable uses is commercial and there is free access to all members of the public, including children. The use includes day-care centres, buildings for religious services, hospitals and medical clinics. It does not include operations where food is grown. The municipal land use zoning restrictions must be consulted to determine the most restrictive land use permitted under the existing zoning. For example, some commercial land uses may permit residential development where the residential remediation criteria would apply.

Industrial Land Use is where the primary activity involves the production, manufacture or construction or servicing of goods. Public access is restricted and children are not permitted continuous access or occupancy. As above, the municipal land use zoning restrictions must be consulted to determine the most restrictive land use permitted under the existing zoning.

3.4.2 Selection of Applicable Exposure Pathways

There is a wide range of exposure pathways by which the chemicals of concern may reach human and ecological receptors. The pathways considered in these Guidelines are adapted from CCME 2000 and are summarized below.

Human Pathways:

- soil ingestion
- soil dermal contact
- inhalation of indoor air
- *protection of potable groundwater

Ecological Pathways:

- plant/invertebrate soil contact
- *protection of groundwater for aquatic life

The pathways without an asterisk (*) are always considered if applicable to the land use. The groundwater pathways marked with an asterisk may be excluded in the following circumstances:

- The human ingestion of groundwater pathway may be excluded if either:

  (i) the site is not underlain by an aquifer used or has the potential for use for domestic water supplies, or

  (ii) the contaminated soil and groundwater is not hydraulically connected to an underlying aquifer used or has the potential for use for domestic water supplies.

  As a guide, water-bearing units with a hydraulic conductivity less than 10^{-6} m/s are unlikely to be considered as an aquifer for domestic water supplies (Alberta Environment, 2001). There are situations where low permeability units may be the only groundwater resource available for domestic use, so local water well records should always be checked during the site investigation stage.

- The protection of groundwater for freshwater aquatic life and wildlife watering pathways may both be excluded in cases where there is no surface water body (e.g., creek, lake, slough) within 300 m downgradient of the site. Downgradient is defined as any direction within 45 degrees either side of the direction of groundwater flow.

3.4.3 Modifying the Land Use

Where the PST site is adjacent to a property where more stringent remediation criteria apply, the remediation criteria for the adjacent property must be applied within the PST site to a distance of 30 metres from the shared property line. The intent of this modification is to prohibit development restrictions being unduly placed on the adjacent land. For example, if the PST site is zoned as commercial but is adjacent to a residential property, then the residential land use criteria are applied to the 30 metres from the property line within the commercial PST site. Depending on the adjacent land uses and the size of the PST property, there may be more than one set of criteria applied to a remediation project.

3.4.4 Depth of Remediation

The soil remediation criteria were selected to achieve maximum flexibility within a land use category and are applied to the full depth of remediation. This approach allows site re-use without special management considerations. For example, re-grading or future excavation may be carried out without concern that contaminated material at depth could be brought to the surface and pose unacceptable risks to human health and the environment. Stratified remediation, or remediation to the subsoil criteria presented by

Alberta Environment (2001), is a risk management option available to Proponents having care and control of the property until generic criteria are met and who are willing to maintain a risk management system on the property for as long as is necessary.

3.5 Modification of Generic Criteria

In certain cases the Proponent may not consider that remediation to the generic criteria specified by the land use assessment is either feasible or appropriate. In such cases the Proponent may modify generic remediation criteria (Tier 2) for the specific set of site conditions, land use and exposure scenarios involved to develop objectives that are equivalent to the generic criteria. The Proponent is expected to support any modification with measured site-specific data.

3.5.1 Adjustments for the Human Inhalation and Groundwater Protection Pathways

Simple adjustments are permitted in the parameters used to develop the soil criteria for the human inhalation and groundwater protection pathways. The process and limitations are presented under Tier 2 adjustments in the *Alberta Soil and Water Quality Guidelines for Hydrocarbons at Upstream Oil and Gas Facilities*.

3.5.2 Alternate Land Use or Receptors

The guidelines developed by Alberta Environment for upstream oil and gas facilities include additional land uses (natural areas, agriculture) and a wider range of human and ecological receptors (livestock/wildlife ingestion of water, soil and fodder) than included in Tables 1, 2 and 3. Where appropriate the Proponent may use the process and numerical criteria presented in the *Alberta Soil and Water Quality Guidelines for Hydrocarbons at Upstream Oil and Gas Facilities* to address other land uses or develop numerical remediation objectives for receptors other than those represented in Tables 1, 2 and 3.

3.6 Site-Specific Risk Assessment

A site-specific risk assessment is a second option for development of risk management objectives (Tier 3) as an alternative to complete site remediation. These alternative risk management objectives incorporate other forms of risk reduction such as exposure barriers and administrative land use controls (AENV, 2000). Professionals who are experienced in risk assessment methodology must perform the site-specific risk assessment. Explicit technical and/or land use assumptions made in the site-specific risk assessment can also become risk management objectives that require long-term management on the affected property. A site-specific risk assessment may require detailed information in addition to that provided by the initial site investigation and therefore the Proponent may be committing to an additional site investigation together with associated monitoring and laboratory analyses.

Based on the detailed site-specific risk assessment, the Proponent would be expected to develop a risk management plan that provides an equivalent level of health and environmental protection as the generic numerical remediation criteria used in the development of these Guidelines.

3.6.1. Risk Management/Risk Reduction Plans

In the risk management plan, the Proponent may propose implementation of risk management or risk reduction measures which would, in conjunction with periodic monitoring and re-evaluation, reduce or eliminate the opportunity for human or environmental impact by controlling exposure pathways. These programs fall into the general category of physical exposure barriers and administrative land use controls. Such measures must be designed on the basis of a detailed risk assessment. The risk management plan submitted to the Department will include criteria for measuring success and a schedule for reporting monitoring results and assessing progress. Measures to be taken in implementing this plan require review and acceptance by the Department. The Department will document its understanding of the risk management plan with emphasis on the ongoing responsibilities of the Proponent for monitoring, maintaining and reporting its effectiveness.

Once implemented, any risk management/risk reduction measures would have to be maintained indefinitely, unless further remediation was carried out and/or generic (or modified) remedial criteria were met and verified by additional assessment. The Department will not issue an acknowledgement of completion for a risk managed site because the plan requires ongoing maintenance by a responsible party.

3.6.1.1 Stakeholder Input to the Risk Management Plan

Since the risk management option potentially leaves in place contaminant concentrations greater than generic (or modified) risk-based remediation criteria, or may impose long-term management obligations on an affected party, Stakeholder input to the risk management/risk reduction plan may be required as determined by the Department. For example, if the contaminant concentration exceeds applicable criteria on a property not controlled by the Proponent, then the Proponent must obtain acceptance from the affected Stakeholder(s) prior to submitting the plan to the Department. Furthermore, if the site-specific risk assessment and risk management plan is based upon restrictions on allowable land use or site accessibility within the relevant zoning category, the affected landowner must be willing and able to undertake the required land use restrictions.

The Department can provide regulatory and technical guidance in the risk management decision process. In the absence of agreement by a directly affected stakeholder, the Department requires compliance with generic (or modified) criteria.

3.7 Department Acceptance for Site Remediation or Management Plans

The risk assessment and remediation process shown in Drawing No. 3.1 and described above identifies several points where acceptance is required from the Department before the Proponent proceeds with site remediation or risk management plans. If, in the opinion of the Department, acceptance is not warranted due to an unacceptable level of risk remaining in place, the

Department will direct the Proponent to provide another site management option. In some cases this other option may require more direct action on the part of the Proponent to protect human health, safety and the environment.

3.8 Verification of Remediation

Upon completion of the remediation process or, in the case of long-term risk management measures, at appropriate intervals during the risk management process testing will be required to confirm the fulfilment of the Department's requirements. Principally this will require analysis of contaminant concentrations in soil and/or groundwater relative to the accepted risk management objectives, and may also involve the monitoring of concentrations at potential points of exposure identified in the risk assessment.

The requirements for verification of soil and groundwater remediation are discussed in Appendix B.

The Department offers an acknowledgement of completion on sites remediated to generic criteria or modified generic criteria. An acknowledgement of completion will not be issued for contaminated PST sites managed by means other than remediation because alternative risk management methods depend on the future diligence of those managing the site.

TABLES

Table 1. Generic Hydrocarbon and Lead Guidelines for Fine-Grained Soil

Table 2. Generic Hydrocarbon and Lead Guidelines for Coarse-Grained Soil

Table 3. Generic Hydrocarbon Criteria for Groundwater

Table 4. Generic Hydrocarbon Criteria for the Groundwater Ingestion Pathway

Table 1. Generic Hydrocarbon and Lead Criteria for Fine-Grained Soil

Land Use	Benzene (mg/kg)	Toluene (mg/kg)	Ethyl benzene (mg/kg)	Xylenes (mg/kg)	Lead (mg/kg)	F1 (mg/kg)	F2 (mg/kg)	F3 (mg/kg)	F4 (mg/kg)
Residential	1.9	300	450	500	140	260	900	800	5,600
Commercial / Industrial	9	450	690	1,500	260 / 600	660	1,500	2,500	6,600
Freshwater Aquatic Life*	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA = not applicable

* = may not apply at a particular site

Table 2. Generic Hydrocarbon and Lead Criteria for Coarse-Grained Soil

Land Use	Benzene (mg/kg)	Toluene (mg/kg)	Ethyl benzene (mg/kg)	Xylenes (mg/kg)	Lead (mg/kg)	F1 (mg/kg)	F2 (mg/kg)	F3 (mg/kg)	F4 (mg/kg)
Residential	0.048	24	54	14	140	30	150	400	2,800
Commercial / Industrial	0.55	71	200	130	260 / 600	310	760	1700	3,300
Freshwater Aquatic Life*	1.6	0.16	79	59	NA	360	230	NA	NA

NA = not applicable

* = may not apply at a particular site

Table 3. Generic Hydrocarbon Criteria for Groundwater

Criteria	Benzene (mg/L)	Toluene (mg/L)	Ethylbenzene (mg/L)	Xylenes (mg/L)	F1 (mg/L)	F2 (mg/L)
Fine-Grained Soils						
Residential	3.5	228	NG	163	9	11
Commercial/Industrial	16	342	NG	NG	24	18
Coarse-Grained Soils						
Residential	0.09	19	19	5	1	2
Commercial/Industrial	1	55	71	43	10	9
All Soils; Piezometers <10 m from Surface Water Body						
Freshwater Aquatic Life*	0.370	0.002	0.090	0.180	NG	NG
Fine-Grained Soils; Piezometers >10 m from Surface Water Body						
Freshwater Aquatic Life*	NG	NG	NG	NG	NG	NG
Coarse-Grained Soils; Piezometers >10 m from Surface Water Body						
Freshwater Aquatic Life*	0.53	0.021	4.8	3.3	NG	NG

NG = no guideline required for this pathway; limited by solubility

* = may not apply at a particular site

Table 4. Generic Hydrocarbon Criteria for the Groundwater Ingestion Pathway

Medium	Soil Texture	Benzene	Toluene	Ethylbenzene	Xylenes	F1	F2	F3	F4
Soil (mg/kg)	Fine-Grained Soil	0.073	0.86	0.19	25	1900	2600	NA	NA
	Coarse-Grained Soil	0.13	1.6	0.36	49	3700	5100	NA	NA
Groundwater (mg/L)	All Soil Textures	0.005	0.024	0.0024	0.3	5	2	NA	NA

NA = not applicable

APPENDICES

Appendix A. Site Investigation Requirements

Appendix B. Remediation Monitoring and Verification Requirements

1.0 GENERAL

This section summarizes the site and subsurface information required in the site assessment and remediation process. The primary purpose of the site investigation is to determine the nature and extent of contamination. The information collected in the investigation will provide the basis for evaluating potential impacts on land use and the environment. The information will also be used to formulate a remediation plan.

Site information, investigation and testing requirements are summarized in Table A-1. The requirements are discussed in the following paragraphs.

2.0 PHASE I ASSESSMENT

The following information can be obtained through a site inspection and a review of available technical information:

A) Surrounding Land Use

- type of municipality (city, town, village etc.)
- land use assessment for the site and other properties within 100 m of site

B) Groundwater Usage

- distance and direction of all wells within 500 m and their ownership and use (private, municipal, domestic, irrigation etc.)
- depth to usable aquifer
- evidence of groundwater discharge to surface water bodies
- major subsurface drainage direction (if known)

C) Surface Water

- surface water bodies within 300 m
- type of surface water (lake, creek, dugout etc.)
- local surface drainage direction
- downstream users

D) Nearby Underground Structures

- presence of basements or similar underground structures within 100 m

- distance to nearest underground structure in each direction
- presence of buried utilities, vaults etc. on or adjacent to site

E) Surficial Geology

- review of geological maps, reports and well records
- nature, lateral extent and continuity of surficial deposits
- depth to, and nature of, bedrock

F) Other Environmental Conditions

- presence of human or environmental conditions requiring special protection or precautions

G) Historical Operation Information

- Historical summary (e.g. year site first used as PST facility, air photo review, location of previous PSTs on the property)
- Meter, dip test and inventory control records; precision tank testing records
- Tank system information
- Operational information (repairs, removals, remediation activities)
- Inspection of tank excavation

Details for conducting a Phase I Assessment can be found in the Canadian Standards Association information product Z768-94, *Phase I Environmental Site Assessment.*

3.0 PHASE II ASSESSMENT

The following information on subsurface conditions is required as a minimum to assess the degree and nature of contamination and for development of a risk management plan.

A) Soil

i) Physical Description

- soil profile description beneath site
- permeability of soil units
- nature of surface course (pavement, gravel, topsoil, vegetation etc.)

ii) Contamination

- depth and lateral extent of soil contamination
- type, age and source of released contaminant
- concentrations of contaminants in soil

- distribution, concentration and composition of subsurface vapours
- presence of phase-separated product in soil

B) Groundwater Conditions

i) Physical Description

- depth to water table
- principal direction of groundwater flow
- thickness of water table aquifer (if required)
- presence and direction of vertical gradients
- characteristics of other usable aquifers if relevant

ii) Contamination

- presence and extent of phase-separated product at water table
- concentrations of dissolved constituents in groundwater

Details for conducting a Phase II Assessment can be found in the Canadian Standards Association information product Z769-00, *Phase II Environmental Site Assessment.*

4.0 SITE INVESTIGATION METHODOLOGY

4.1 Introduction

The purpose of this section is to provide a summary description of an acceptable investigation approach and methodology for subsurface tank leak/spill investigations. The methodology presented in the following discussion is intended mainly for the benefit of PST owners, operators and managers charged with ensuring execution of a proper site assessment. Adherence to the recommended methodology will permit adoption of a unified investigative approach for most PST site assessments conducted in Alberta.

Although one set of standard investigation methods cannot be developed to fully apply to every situation on site, the approach and methods presented are generally acceptable for most site conditions. However, as numerous substances are stored in petroleum storage tanks in addition to hydrocarbon fuels, major portions of the recommended approach and methodology may not be suitable for sites potentially affected by contaminants other than hydrocarbon fuel. The scope and methodology presented in this section is therefore limited to hydrocarbon fuels.

In all investigations, experienced contamination assessment professionals should be consulted and their judgement relied upon to design the most effective investigation program for any given site or contaminant. It is also recommended that an experienced assessment team that is well qualified in the appropriate engineering and science disciplines conduct the site investigation. It is necessary to rely on this professional investigation team for the evaluation of information needs, the integration of all site specific information into an effective investigation/sampling

plan, proper collection of representative samples, interpretation of the resulting data, and ultimately for the provision of an assessment which is responsive to both the regulatory and scientific objectives outlined in this guidance document.

4.2 Investigation/Sampling Plan

The initial and perhaps most critical element of a petroleum storage tank site assessment is the investigation/sampling plan. The purpose of the plan is to ensure the collection of all data required to define the extent and degree of subsurface contamination. Site-specific knowledge is required to design and execute an effective plan. A site reconnaissance is necessary to become familiar with the site and provide information required for plan development and implementation. Site-specific factors include:

- site history and adjacent land use
- site infrastructures
- location of underground tanks and associated facilities
- past and present contents of tanks
- source, type, and estimated volume of released contaminants
- surficial geology, hydrology, and hydrogeology
- preferential migration pathways and proximity of receptors
- underground utilities and services
- potential hazards and accessibility

Preliminary hydrocarbon vapour surveys may also assist the planning of a more detailed investigation at some sites. This preliminary survey generally involves the mapping of subsurface vapour concentrations based on a grid of shallow probe holes.

An investigation/sampling plan must describe the individual tasks and sampling effort, as well as when and how they will be performed. For proper interpretation and evaluation of collected data, the data must be generated by a scientifically effective sampling program.

Key components of the plan should include:

- field equipment requirements
- borehole location patterns for on-site and off-site investigations
- groundwater monitoring well location, design, and construction
- soil sampling strategy and equipment
- groundwater monitoring and sampling strategy
- sample preservation and analytical considerations
- quality assurance and quality control program
- personnel and public health and safety requirements

Site specific knowledge of contaminant pathways and the influence of geologic, hydrologic, chemical and other forces in the subsurface, is often far from complete prior to initiation of field investigations. Subsurface assessments generally require a phased approach, regardless of the initially perceived size or scope of investigation.

The investigation/sampling plan should be comprehensive as it, together with the skill, training, and experience of the field investigators, will largely determine the assessment program's success. Because the sample handling and analytical requirements are also essential components of the plan, it is advised the laboratory chemist be included in the plan's development.

The approach and methodology for field and laboratory investigation components of the plan, are discussed in the following sub-sections.

4.3 Characterization Program

4.3.1 Quality Assurance and Quality Control

Quality Assurance (QA) is a systematic process for ensuring that all collected data and the decisions based on these data are technically sound, statistically valid, and properly documented. The program involves a series of steps, procedures and practices required to ensure a specified degree of confidence. Quality Control (QC) procedures are the methods employed to measure the degree to which the quality assurance objectives are met.

General QA and QC measures which should be employed for subsurface site assessments include:

a) Use of proven and appropriate investigation methods, such as those recommended in this section, by trained field and laboratory personnel;

b) Care and calibration of all field equipment, sampling apparatus and instruments to ensure they are clean, calibrated, and in good working condition;

c) Documentation of all field and laboratory activities so that sample results may be evaluated correctly with respect to site conditions, sample collection and handling methods, and sample analyses;

d) Use of field quality control measures which require field blanks and duplicate sample analyses to detect contamination during handling and transport, and document analysis precision; and

e) Coordination with the analyzing laboratory for the preparation of sampling containers, and for preservation, packaging, shipping and receipt of samples to ensure that meaningful data will result from timely analyses of valid samples.

In addition to the above general requirements, laboratory QA/QC protocols must be employed in the analytical portion of the assessment program.

4.3.2 Field Investigations

The evaluation and initial selection of the number, locations, spacing and monitoring frequency of subsoil boreholes and groundwater wells needed to define and/or monitor any contamination requires an assessment of specific site characteristics.

The nature of the contamination, if known, the potential sources of contamination and the location of potential migration pathways are considered in relation to the local geology and hydrogeology. Actual final field placement will most often depend, not only on pre-targeted locations and depths, but on the progressive field evaluation of additional needs as indicated by the surface and subsurface conditions encountered during drilling.

Field methods include:

- borehole investigation and soil sampling techniques
- field hydrocarbon vapour measurements
- groundwater monitoring well design and installation
- groundwater monitoring and sampling

4.3.2.1 Subsoil Investigations

Investigative boreholes are normally augered using a mobile drilling rig equipped with necessary drilling and sampling devices to define subsurface conditions. A standard 50 mm diameter split spoon sampler is generally the preferred soil sampling device.

Subsoil samples should be collected at 0.75 meter intervals and at every stratigraphic change. Sampling depths are entirely site specific and will normally depend upon field observations. Subsoil stratigraphy at each borehole location should be logged and subsoil units classified according to the Unified Soil Classification System[1]. Any visual anomalies and evidence of contamination should also be recorded. A typical borehole log is presented in Figure 1.

Soil Samples

The retrieved split-spoon soil sample should be trimmed and approximately 20 mm at each end discarded to minimize cross contamination of samples. A representative portion of the sample is then divided longitudinally; one half (laboratory sample) is transferred with minimum headspace to a laboratory sample container, which is capped, labelled, and stored on site in ice filled coolers. The second half (field sample) is reserved for field

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1 "Unified Soil Classification System", Technical Memorandum 3-357 prepared for Office, Chief of Engineering, by Waterways Experiment Station, Vicksburg, Mississippi, Corps of Engineers, U.S. Army. Vol 1, March 1953.

vapour screening. Laboratory sample containers should be glass and must have tight screw-type lids with foil or Teflon cap liners. Laboratory samples should be transported immediately at the completion of daily field investigations, along with chain of custody documentation, to the analyzing laboratory.

Sampling tools and equipment should be properly cleaned between successive samples to prevent cross-contamination. Generally organic-free detergent and water solutions are effective cleaning agents when followed by distilled water rinses. In some cases (i.e. oily contaminants) additional cleaning with organic solvents (i.e. acetone, methanol, or methylene chloride) may be required.

Field Hydrocarbon Vapour Screening

To guide the drilling operation and provide a preliminary evaluation of subsoil contamination, the reserved field sample is analyzed for volatile vapours using a hydrocarbon vapour analyzer[2]. Field vapour levels should always be measured on the reserved field subsample which is then discarded. They should not be measured on the subsample which is to be returned to the laboratory for analysis.

Soil samples for vapour analysis are transferred to glass containers fitted with modified lids, which include a tape sealed probe-hole located in the top of the lid. The container is filled with sample to a 50% volume mark, to provide adequate headspace for the accumulation of released vapours. Samples are usually broken by hand to increase surface area and permit vapour release. The transfer of sample to the container should be accomplished quickly to minimize vapour loss.

The capped container is then manually shaken vigorously for 15 seconds and left to stand upright and undisturbed for a period of approximately 5 minutes, at an ambient temperature of 20°C ± 5°C.

The concentration of accumulated vapours in the headspace is then measured by puncturing the probe-hole tape seal and inserting a hydrocarbon vapour analyzer probe. The analyzer must be calibrated to known hydrocarbon standards. Measured vapour concentrations are recorded in a field log for comparison with subsequent samples and boreholes.

Upon completion, all boreholes drilled for descriptive logging and subsoil sampling purposes only, should be sealed with bentonite clay to minimize potential pathways for contaminant migration. Drill cuttings should not be used as backfill as they may not provide an adequate seal and may contribute to cross-contamination.

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2 Various hydrocarbon analyzers are available, which incorporate different detection systems (i.e. thermal conductivity, flame ionization and photo ionization detectors). Instrument calibration curves for standard hydrocarbon fuels, should be prepared to assess selected instrument response prior to field use.

4.3.2.2 Groundwater Evaluations

Monitoring Well Location

Monitoring wells are constructed as standpipe piezometers and should be placed in locations surrounding the suspected sources of groundwater contamination. Although most wells will be constructed downgradient from the suspected source, upgradient and lateral locations are required for both background assessment and evaluation of the geological setting.

Some of the monitoring wells may be installed in subsoil sampling boreholes. However, it should be recognized that these may not always be logical locations for well placements.

Design and Installation of Monitoring Wells

Groundwater monitoring wells should be constructed with flush-joint, threaded pipe casings which have a minimum inside diameter of 50 mm. These are installed in a boring whose diameter is at least 100 mm greater than the diameter of the casing. PVC or stainless steel casing and screen material is recommended.

Monitoring wells should be constructed as filter-packed wells so that particles of natural soil cannot enter. A uniform sandpack is recommended. The well screen should be factory perforated with a slot size adequate to prevent entry of filter material. Filter packs should extend approximately 0.5 m above the perforated screen interval to allow for compaction of the filter material. All standpipes shall have a bottom cap or plug.

Proper well construction is essential to ensure the monitoring well itself does not become a route for contaminant migration. Wells should be constructed where possible to provide depth discrete measurements for individual "flow" zones. Slotted screen intervals must be located to coincide with the groundwater surface in order to measure the accumulated thickness of any phase-separated hydrocarbon product (free product). Installation of a continuously slotted screen that cuts across and links several flow zones should be avoided to minimize the risk of cross zone contamination. This is of particular concern in subsoil units where free product is evident, and in areas where the location of the stabilized groundwater surface is unknown or where large seasonal fluctuations may occur. In these areas, a "nest" of several piezometers (installed in separate adjacent boreholes) with slotted screen intervals at varying depths is recommended to enable independent observation of several horizons or flow zones.

Groundwater monitoring wells should be sealed from the top of the filter pack to the ground surface. The backfill material installed above the filter pack should be a low permeability material with known chemical properties (e.g. bentonite). The use of drill cuttings as backfill will not ensure an adequate seal. The uppermost metre of the well annulus should be backfilled with a concrete grout. The grout should extend above the ground surface and be finished to slope away from the well. This concrete plug and

apron will inhibit downhole infiltration of surface water. Well heads should be fitted with a watertight cap and enclosed in a structure that secures the well against accidental damage, unauthorized access, and vandalism.

The recommended design for the construction of standpipe piezometers is presented in Figure 2. In some instances it may be necessary to target more than one permeable stratum in order to assess the possibility of vertical hydrocarbon migration. In this case a nest of standpipe piezometers would have to be constructed. The individual piezometers would be constructed as shown in Figure 2, but screens and annular seals would have to be carefully constructed to isolate the individual strata and prevent cross-contamination.

Subsoil stratigraphy and lithology should be logged and subsoil units classified according to the Unified Soil Classification system prior to the well construction. A sketch of each well constructed should be prepared to accompany visual observations and apparent groundwater levels recorded on the borehole/well log. All wells should be surveyed relative to a suitable benchmark for the measurement and evaluation of groundwater elevations.

Groundwater Monitoring and Sampling

All monitoring wells should be monitored for water levels and the presence of any phase-separated (free) hydrocarbon product floating on the water surface. If free product is present its thickness should first be measured using an interface device (i.e. sonic interface probe). Where possible, the free product should be removed, its volume recorded, and additional monitoring conducted to determine product recovery rates. Samples of free product should be collected for laboratory characterization of the contaminant.

It is essential that water levels stabilize prior to use of the elevation data to assess groundwater flow. Monitoring of water levels and free product thickness should be conducted at least twice and on separate site visits. The actual number of monitorings will depend on well stabilization rates.

Prior to sampling of groundwater for dissolved constituent analyses, the well must be purged to remove all stagnant water retained in the standpipe. Pumping or bailing of at least four times the calculated standpipe water volume or to dryness is recommended. The groundwater sample may then be collected using a bailer or other suitable device and transferred to 1000 ml laboratory sample containers. Duplicate samples are recommended. The containers should be glass and must have tight screw-type lids with foil or Teflon cap liners. Collected samples should have no visible headspace or evidence of any free product. Samples should be stored in ice filled coolers while on site, and transported immediately after sampling to the analyzing laboratory, along with chain of custody documentation.

Dedicated sampling devices should be used for each well installation, or equipment must be thoroughly cleaned between successive well samplings.

4.3.3 Laboratory Investigations

The number of soil and groundwater samples submitted for laboratory examination must be sufficient to quantify the total extent (both vertical and lateral) and degree of subsurface soil and groundwater contamination.

Analysis parameters will include, but may not be limited to:

- Aromatics which include benzene, toluene, ethylbenzene and xylenes
- Petroleum hydrocarbon fractions
  - F1: $C_6 - C_{10}$
  - F2: $>C_{10} - C_{16}$
  - F3: $>C_{16} - C_{34}$
  - F4: $>C_{34}$
- Lead.

Recommended laboratory methods for the analyses of soil and groundwater samples are those of the Canadian Council of Ministers of the Environment (2001)[3] and United States Environmental Protection Agency (EPA)[4]. Flowcharts for analyses are presented in Figures 3 and 4 for soil and water samples respectively. As other analytical methods are available, investigators should consult the analyzing laboratory to ensure that alternate methodology will provide acceptable data.

Alternate analytical methods should provide detection limits as well as precision and accuracy levels equivalent to or better than the referenced EPA methods.

Selection of a particular method will depend on sample matrices, contaminant(s) and concentration of the analytes as well as available analytical instrumentation.

Sample holding times and preservation requirements are presented in Tables A-2 and A-3.

Initial analytical workup for contaminant identification should include qualitative analysis of selected samples. These may be samples with elevated field vapour levels and/or free product from monitoring wells to characterize or confirm the hydrocarbon

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3 Canadian Council of Ministers of the Environment. 2001. Reference Method for the Canada-Wide Standard for Petroleum Hydrocarbons in Soil – Tier 1 Method.

4 U.S. EPA. 1986. Test Methods for Evaluating Solid Waste; Physical/Chemical Methods. SW-846, Third Edition. Office of Solid Waste and Emergency Response, U.S. EPA, Washington, D.C.
U.S. EPA. 1983. Methods for Chemical Analysis of Water and Wastes. EPA 600/4-79-020, Revised March 1983. U.S. EPA Environmental Monitoring Laboratory, Cincinnati, OH.

contaminant. Quantitative methods should then be chosen which are appropriate for the identified contaminant(s).

Laboratories that perform analysis of collected samples should evaluate their QA/QC programs against the required analytical procedures. QC procedures should include the analysis of duplicate spike samples, blanks (field and reagent), check samples and surrogate standard recoveries. Appropriate QA and QC measures should be used to ensure all data generated is suitable for the objectives of this investigation.

5.0 REPORT SUBMISSIONS

Reporting should include:

A) Introduction

- proponent's name and address;
- investigator's name and address; and
- site legal description or municipal address.

B) Background

- site occupants or businesses, relevant site history, and identified contaminant releases.

C) Site Description

- site and surrounding land use;
- on-site and adjoining infrastructures;
- applicable site and surrounding land use maps showing site location, infrastructures, and underground tank facilities; and
- photographs.

D) Field Investigations

- investigation/sampling plan and QA/QC summary;
- detailed procedures used for subsoil and groundwater evaluations;
- borehole and monitoring well location plan at an appropriate scale;
- borehole logs and monitoring well construction drawings and details;
- field hydrocarbon vapour measurements; and
- groundwater monitoring data and free product measurements.

E) Laboratory Investigations

- identified contaminant(s);
- analysis rationale (i.e. number of samples and parameters);
- soil and groundwater analysis results with supporting documentation; and
- laboratory QA/QC procedures and QC sample results.

F) Data Evaluation

- subsurface contamination encountered;
- field hydrocarbon vapour measurements and laboratory sample analysis correlations;
- groundwater/free product evaluations; and
- laboratory analyses interpretation;

G) Site Assessment

- extent and degree of identified subsurface contamination;
- contaminant concentrations in context of cited criteria; and
- environmental conditions and public health and safety concerns.

H) Conclusions and Recommendations

- immediate response requirements;
- land use assessment;
- remedial action required, risk management level feasible, and available remediation options; and
- additional investigations required.

TABLE A-1

Summary of Site Information, Subsurface Investigation and Testing Requirements

	SITE INFORMATION	SUBSURFACE EVALUATION	SITE-SPECIFIC RISK ASSESSMENT
BACKGROUND INFORMATION			
On Site and Surrounding Land Use	X	X	X
Groundwater Use	X	X	X
Surface Water Use	X	X	X
Nearby Underground Structures	X	X	X
Other Environmental Conditions	X	X	X
Surficial Geology	X	X	X
SUBSURFACE CONDITIONS			
Soil Conditions	O	X	X
Groundwater Conditions	O	X	X
NATURE AND EXTENT OF CONTAMINATION			
Presence of Visible Contamination	X	X	X
Shallow Combustible Vapour Concentrations	R	R	R
Combustible Vapour Concentrations			
• in soil samples	O	X	X
• in boreholes	O	X	X
• offsite	O	X	X
BTEX[a], PHC[b], lead concentrations			
• soil samples	O	X	X
• in groundwater samples	O	X	X
BTEX[a], in subsurface vapours onsite	O	O	X
BTEX[a], in vapours offsite[c]	O	O	X

KEY: X - Required
R - Recommended
O - Optional

NOTES: a - BTEX - Benzene, Toluene, Ethyl Benzene, Xylenes
b - PHC - Petroleum Hydrocarbon Fractions F1-F4
c - Offsite refers to migration pathway or point of exposure

TABLE A-2

Recommended Preservation Techniques and Holding Times For Water Samples

Analyte	Preservation	Maximum Holding Time
Volatiles (BTEX)	Cool, 4°C 0.008% $Na_2S_2O_3$ HCl to pH=2	7 days 14 days with preservative
Lead	Field filtered HNO3 to pH <2	6 months

TABLE A-3

Holding Time for Soil Samples

Analyte	Preservation	Holding Time
Volatiles (BTEX)	Cool, 4°C	Analyze as soon as possible (maximum 14 days)
Lead	Cool, 4°C	Analyze as soon as possible

FIGURE 1

CLIENT NAME	SERVICE STATION HYDROCARBON ASSESSMENT	BOREHOLE No. HBT1
	STREET LOCATION	PROJECT No. EG07000
DRILL: B-61 TRUCK MOUNT 6" SOLID AUGER	CITY PROVINCE	ELEVATION 645.56 (m)

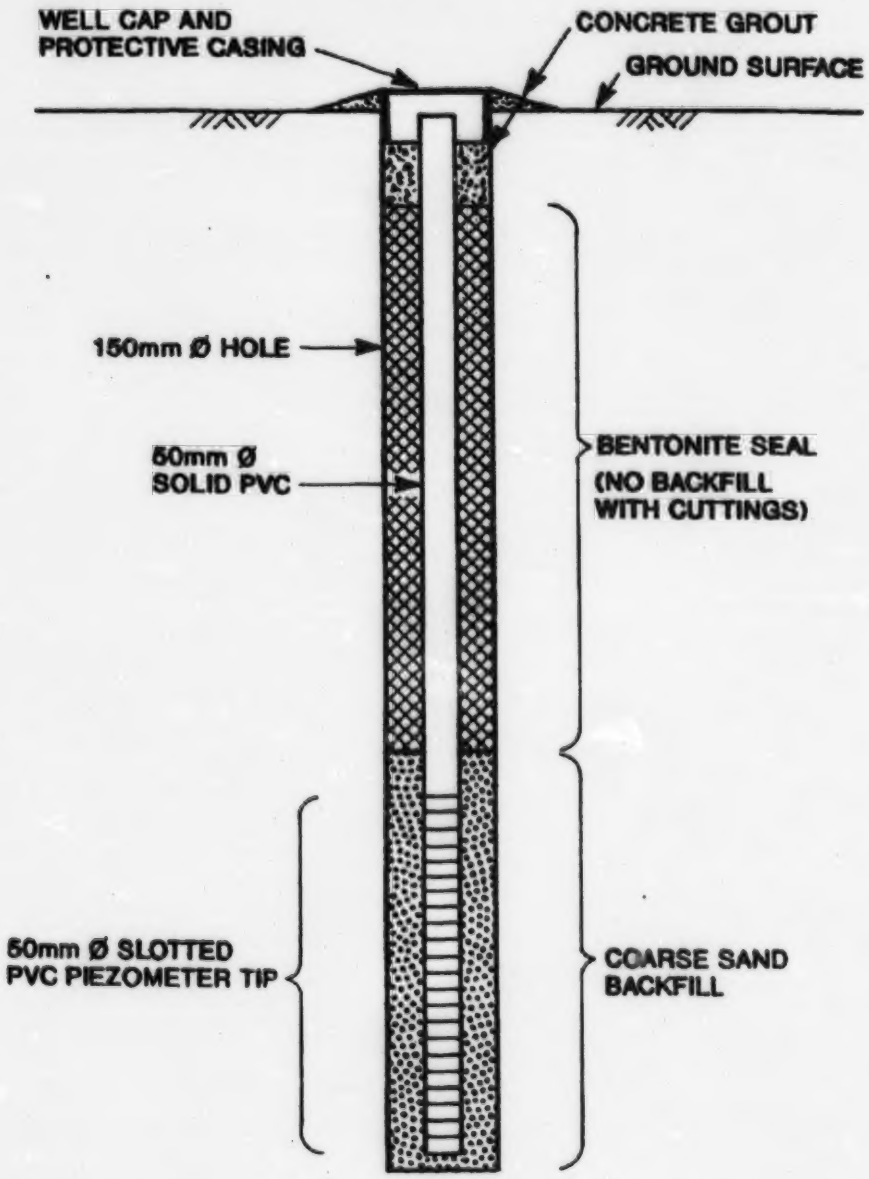
SAMPLE TYPE: SHELBY TUBE | NO RECOVERY | SPT TEST (N) | GRAB SAMPLE | SPLIT PEN | CORE SAMPLE

DEPTH (m)	WELL CONSTRUCTION	USC	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE/SPT(N)	ORGANIC VAPOUR PPM %LEL	DEPTH (m)
0.0		FILL		TOPSOIL (FILL), rootlets, black		G1	OVA = ND	0.0
1.0		FILL		CLAY (FILL), silty, some topsoil, very stiff with peat inclusions to 30mm		G2	OVA = 5 PPMV	1.0
2.0				CLAY, silty, very stiff, medium plasticity, mottled grey and light brown		G3	OVA = 3 PPMV	2.0
3.0						G4	OVA = 50 PPMV	3.0
4.0		CI		trace of weak oxide stains, mottled light olive grey – irridescence, visible hydrocarbon?		G5	OVA = 75 PPMV	4.0
5.0				– damp, occasional rootlet, grey		G6	OVA = 60 PPMV	5.0
6.0				– moist, slickened surface, light		G7	OVA = 110 PPMV	6.0
7.0		MH		SILT, clayey, trace of mica, very stiff low plasicity, massive, olive brown		G8	OVA = 150 PPMV	7.0
8.0						G9	OVA = 120 PPMV	8.0
9.0		CH		CLAY TILL, silty,trace of fine sand inclusions, hard, moist, massive becoming sandy, high plastic		G10	OVA = 175 PPMV	9.0
10.0		MH		SILT, trace silt and clay, fine-grained light brown – trace to some silt, damp, brown		G11	OVA = 220 PPMV	10.0
11.0		CS		CLAY SHALE, silty, high plastic, hard		G12	OVA = 150 PPMV	11.0
12.0		SM		SAND, trace silt, fine-grained, moist		G13	OVA = 80 PPMV	12.0
13.0						G14	OVA = 85 PPMV	13.0
14.0		CL		CLAY, silty, hard, damp, trace of coal specs, low plastic, grey		G15	OVA = 50 PPMV	14.0
15.0						G16	OVA = 20 PPMV	15.0
16.0		CS		CLAY SHALE, silty, hard, trace of coal specks, high plastic, grey		G17	OVA = 5 PPMV	16.0
17.0						G18	OVA = ND	17.0
18.0						G19	OVA = ND	18.0
19.0		COAL		COAL, hard, brittle, occasional grey high plastic shale inclusion		G20	OVA = ND	19.0
20.0						G21	OVA = ND	20.0
21.0		SS		SANDSTONE, well cemented, trace of clay occasional layer of clay shale		G22	OVA = ND	21.0
22.0				End of Hole at 22.0 m Installed 50 mm Diam PVC Standpipe 3.1 m slotted screen at 22.0 m Sand pack to 18.4 m, bentonite to surface No accumulation of freewater at completion W.L. at 18.1m after 2 days		G23	OVA = ND	22.0
23.0						G24	OVA = ND	23.0
24.0						G25	OVA = ND	24.0
25.0						G26	OVA = ND	25.0

OVA = ORGANIC VAPOUR ANALYZER
ND = NON DETECTIBLE
PPMV = PARTS PER MILLION VAPOUR

COMPLETION DEPTH 22.0 m	DATE DRILLED 23/10/90
LOGGED BY MJL	FIGURE 7000-1	Page 1 of 1

FIGURE 2



TYPICAL STANDPIPE PIEZOMETER DETAIL

FIGURE A-3

FLOWCHART OF SOIL ANALYSIS

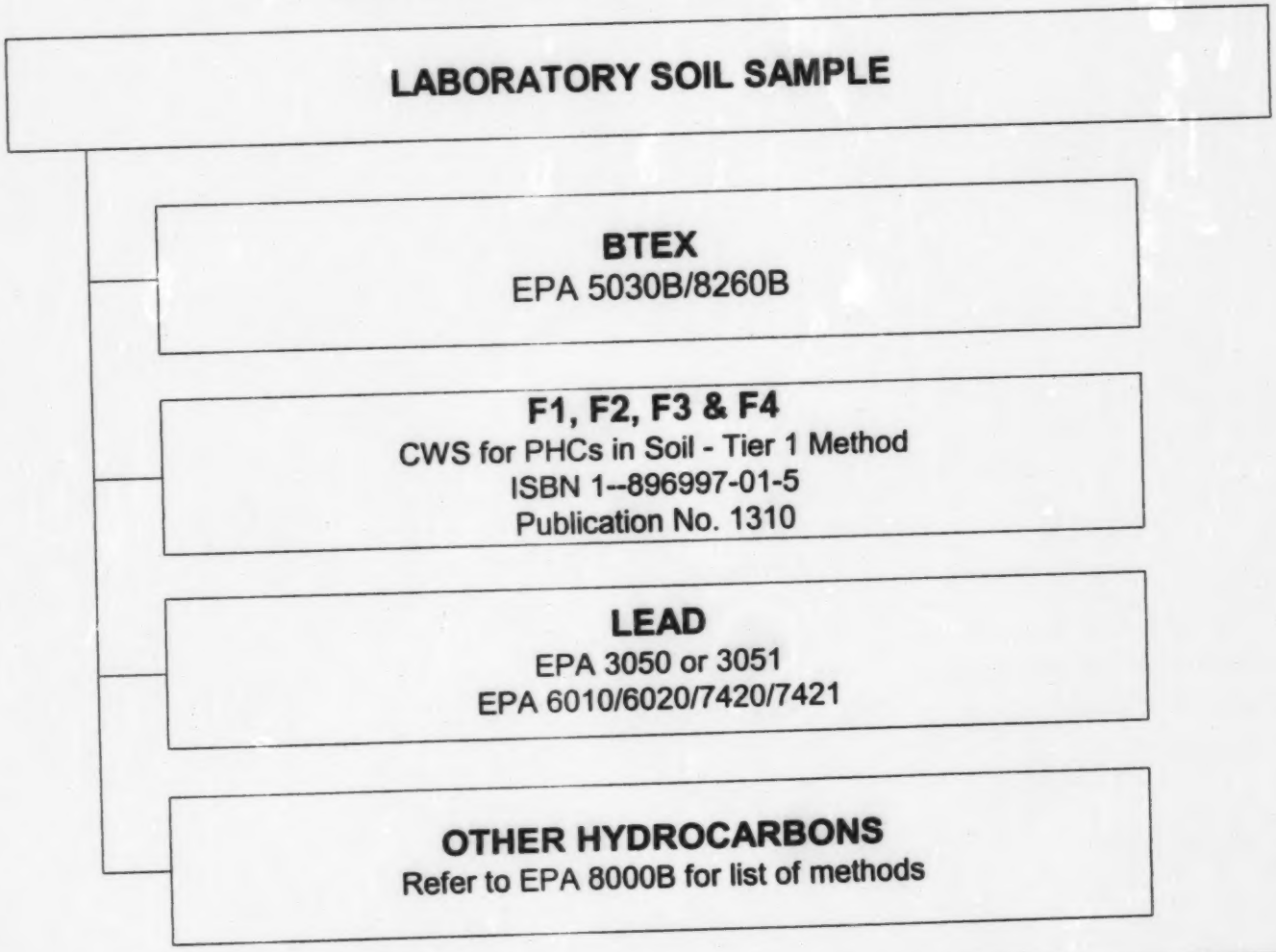
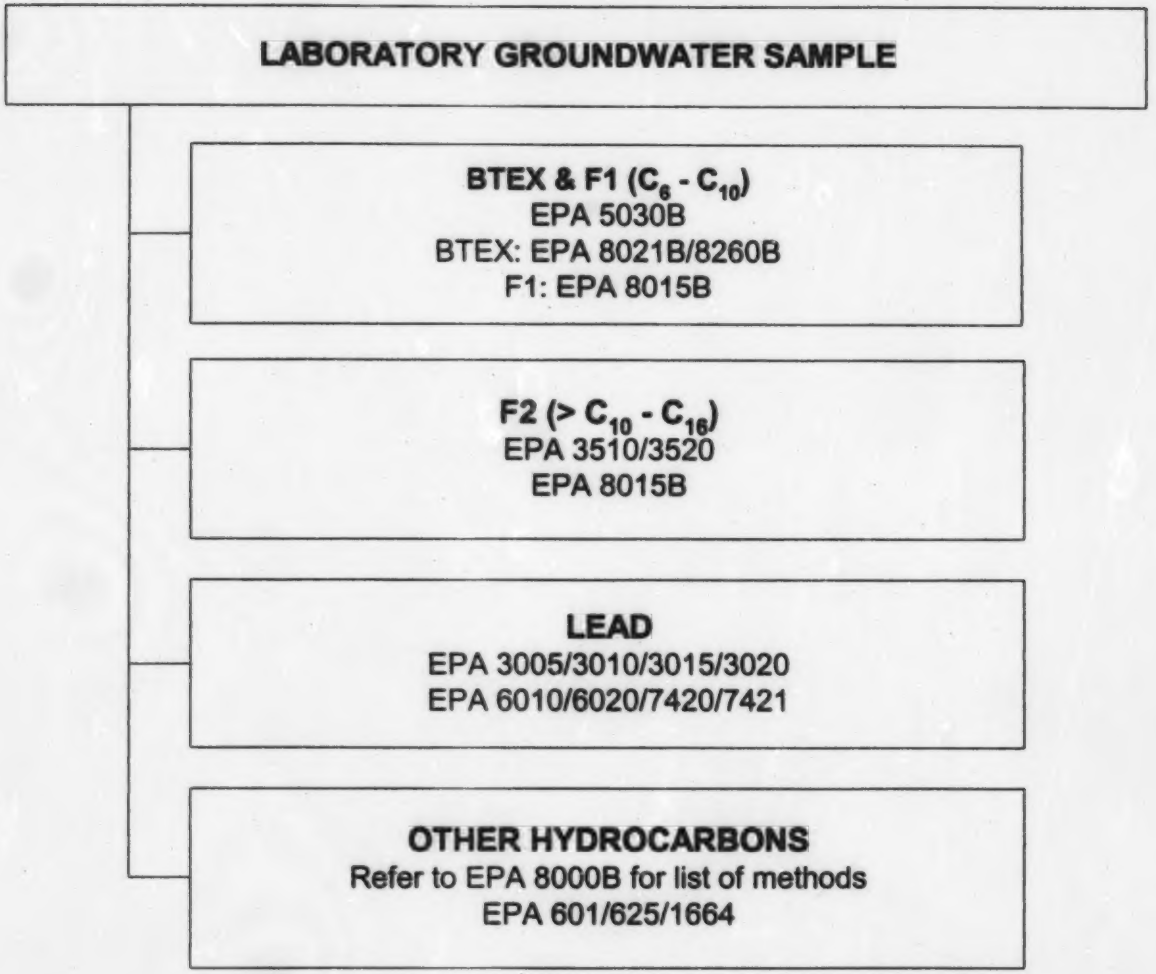


FIGURE A-4

FLOWCHART OF WATER ANALYSIS



1.0 GENERAL

Upon completion of the remediation process, testing will be required to confirm compliance with either the specified numerical criteria established by the Department or the approved risk management criteria developed by the Proponent for the specific site. This will normally comprise the determination of contaminant concentrations remaining at the site relative to the approved criteria, but may also involve the monitoring of concentrations at potential points of exposure identified in the site sensitivity assessment or detailed risk assessment. In the case of long-term remediation measures, additional monitoring and testing will be required at appropriate intervals following implementation of the measures. Ongoing monitoring and testing will also be required in some cases where the scope of the remediation work, for example the extent of excavation, is not determined at the outset.

2.0 MONITORING AND VERIFICATION METHODS

Monitoring and verification may be accomplished in a variety of ways, including:

- sampling and analysis of soil during remediation (including field tests during excavation)
- groundwater monitoring, sampling and analysis
- post-remediation sampling and analysis

The applicability of the available methods for monitoring and verification will depend on the remediation techniques. The requirements are summarized according to remediation technique in Table B-1, and are described below.

A) Excavation and Disposal

Measurement of combustible vapour concentrations as well as the concentrations of benzene, toluene, ethyl benzene, xylenes (BTEX) and lead in both soil and groundwater and petroleum hydrocarbons (PHC) are required to establish compliance with the approved risk management criteria. Optional field screening techniques such as the measurement of combustible vapour concentrations during excavation may be used to facilitate the determination of excavation extent and disposal destination, and as a basis for selecting samples for more detailed testing. However, the limitations of such measurements with respect to quantification of the parameters of interest must be recognized.

B) In Situ Vapour Extraction

In situ vapour extraction is in most cases a long-term remediation technique. As with all remediation methods, confirmation that the remediation meets the accepted criteria requires measurement of the concentrations of BTEX, lead and PHC in representative samples of soil and, where appropriate, groundwater. This will normally be performed following remediation. However, due to the long-term nature of the remediation process, monitoring and analysis should be performed on an ongoing basis to assess the progress of the remediation. Although no criteria presently exist for contaminant concentrations in soil vapours, laboratory analysis of vapour samples is strongly recommended as a means of assessing directly the health risks associated with the contamination remaining at any stage during or following remediation.

C) In Situ Bioremediation

In situ bioremediation, like in situ vapour extraction, is a relatively long-term process and thus requires a certain amount of ongoing monitoring as well as post remedial verification testing. Analysis of soil and groundwater samples to determine concentrations of BTEX and lead will be required to verify completion of the remediation to the approved criteria. In addition, sampling and analysis of the groundwater at intervals during remediation will be required, and ongoing monitoring of monitoring wells to determine groundwater table elevations and subsurface vapour concentrations during remediation is strongly recommended.

D) On-Site Aeration

On-site aeration is a means of soil treatment to permit reuse or disposal of the soil. Obviously, the soil must be tested during and/or following remediation to ensure that it meets the approved remediation criteria or disposal site acceptance requirements. This would normally involve sampling and analyzing the soil to determine concentrations of BTEX, phenols and lead. Monitoring of soil vapour concentrations during the aeration process may be used to assess the progress of the remediation.

The previously contaminated area(s) of the site, from which the soil undergoing aeration was removed, will be subject to the same verification requirements as outlined above for sites remediated through soil excavation and disposal.

E) Liquid Recovery/Groundwater Treatment

Liquid recovery and groundwater treatment are addressed in these guidelines only in so far as they form part of a PST site remediation scheme as opposed to treatment or rehabilitation of an aquifer. The requirements for monitoring and testing during and following remediation are based on the need to ensure that the quality of groundwater returned to the subsurface or otherwise disposed of is within applicable standards and that the effects of the operations on the groundwater regime are acceptable and controlled. Sampling and analysis of groundwater, both from the subsurface and from the treatment

system discharge, will be required periodically to determine concentrations of BTEX and lead. Piezometric levels throughout the area affected by the withdrawal of fluids should be monitored on an ongoing basis.

The requirements that pertain to other means of remediation also apply in this case with respect to ensuring that overall site risk management criteria are met.

The extent of verification testing required in each case will be dictated by a number of factors including the degree to which the extent of contamination was defined in the initial investigation, the remediation approach adopted and the amount and type of testing conducted during remediation.

Methods B to E above encompass a form of risk management. Since these methodologies generally require a long-term management program, the Department may require the Proponent to submit project status reports on a regular basis. Monitoring and reporting schedules could be fairly stringent while the project is in its initial stages but would be reduced as success is demonstrated. Sampling and monitoring of key indicator parameters may be required as frequently as quarterly with future reductions to an annual basis if the method is progressing as predicted.

3.0 REMEDIATION PLAN SUBMISSION OUTLINE

3.1 Report Content and Format

Remediation plan submissions prepared by the proponent should be submitted in two report volumes: the first volume as a project summary report and the second volume containing the detailed remediation plan proposal.

A) Volume One

The Project Summary Report should contain the following material:

1. A cover sheet stating the project name, the name of the proponent, and the name of principal investigators.

2. A project summary providing background information.

3. Site Assessment Report.

4. Land Use Assessment.

5. Site-Specific Risk Assessment (only in certain cases).

B) Volume Two

The Detailed Remediation Plan Proposal should contain the following:

1. A cover sheet stating the project name, the name of the proponent, and the name of principal investigators.

2. A proposal summary stating the remediation plan objectives based on land use and a brief description of the nature of the proposed remedial actions.

3. A description of the proposed remediation plan including appropriate details regarding each plan component:

   - remediation process;
   - implementation strategy;
   - operation and monitoring;
   - contaminant disposal and treatment;
   - reclamation feasibility and impacts;
   - abandonment procedures; and
   - post-remediation site conditions and any applicable landuse restrictions.

4. A description of proposed management plan detailing:

   - schedule;
   - remediation sequence;
   - duration of each remedial activity;
   - remediation monitoring (sampling and analysis program);
   - progress reporting; and
   - long-term management and monitoring requirements.

5. A description of proposed remediation verification testing including:

   - final clearance sampling and verification analysis program.

6. Identification of any adverse environmental impacts that cannot be fully mitigated by proposed remediation plan. Analysis of these impacts in terms of alternative remediation strategies.

TABLE B-1

Summary of Remediation Monitoring and Verification Requirements

PARAMETERS	REMEDIATION TECHNIQUE				
	EXCAVATION & DISPOSAL	IN SITU VAPOUR EXTRACTION	IN SITU BIOREMEDIATION	ON-SITE AERATION	LIQUID RECOVERY G/WATER TREATMENT
Combustible Vapours in Soil Samples	OD, XF	OD	OD	OD	NR
Combustible Vapours in Boreholes	OD, OF	XD	XD, XF	OF	OD, OF
BTEX[a], PHC[b], Lead in Soil Samples	OD, XF	XF	XF	XF	NR
BTEX[a] in Subsurface Vapours	XD, OF	XD[c], XF	XD[c], XF	NR	OD, OF
BTEX[a], PHC[b] in Groundwater	XF	XF[c]	XD, XF	XD[c], XF[c]	XD, XF
Fluid Levels in Boreholes	OF	XD[c], XF[c]	XD, XF	XD[c], XF[c]	XD, XF

KEY TO REQUIREMENTS:

XD - Required During Remediation
XF - Required Following Remediation
OD - Optional During Remediation
OF - Optional Following Remediation
NR - No Requirements

NOTES:

a - BTEX - Benzene, Toluene, Ethyl Benzene, Xylenes
b - PHC - Petroleum Hydrocarbon Fractions F1-F4
c - May not be required by Department in some circumstances